7 | WATER SYSTEM ANALYSIS

INTRODUCTION

This chapter presents the analysis of the City of Kent's (City) existing water system. Individual water system components were analyzed to determine their ability to meet policies and design criteria under existing and future water demand conditions. The policies and design criteria are presented in **Chapter 5**, and the water demands are presented in **Chapter 4**. A description of the water system facilities and current operation is presented in **Chapter 2**. The last section of this chapter presents the existing system capacity analysis that was performed to determine the maximum number of equivalent residential units (ERUs) that can be served by the City's existing water system.

PRESSURE ZONES

The ideal static pressure of water supplied to customers is between 40 and 80 pounds per square inch (psi). Pressures within a water distribution system are commonly as high as 120 psi, requiring pressure reducing valves (PRVs) on individual service lines to reduce the pressure to 80 psi or less. It is difficult for the City's water system (and most others) to maintain distribution pressures between 40 and 80 psi, primarily due to the topography of the water service area.

Table 7-1 lists each of the City's 11 pressure zones (the north and south sections of the 240 Zone and 360 Zone are evaluated separately), the highest and lowest elevation served in each zone, and the minimum and maximum distribution system pressures within each zone based on maximum static water conditions (full reservoirs with no demand). While this table presents the results of the pressure evaluations based on the adequacy of the pressure zones under static conditions, the hydraulic analysis section later in this chapter presents the results of the pressure evaluations based on the adequacy of the water mains under dynamic conditions.

Table 7-1
Minimum and Maximum Distribution System Static Pressures

Pressure Zone	Highest Elevation Served		Lowest Elevation Served	
	Elevation (feet)	Static Pressure (psi)	Elevation (feet)	Static Pressure (psi)
Existing System				
240 Zone	135	46	20	95
271 Alvord Zone	183	38	79	83
308 Hilltop Zone[1]	133	86	119	92
339 Seattle Zone	268	31	74	115
354.5 Zone	272	36	94	113
366 Stetson Zone	234	57	174	83
368 Weiland Zone	219	65	106	114
416 Zone[2]	312	45	83	144
485 Zone	397	38	154	143
529 Zone	434	41	277	109
575 Zone	445	56	408	73
587 Zone	454	58	327	112
590 Zone	504	37	286	132
Projected 20-year System with Improvements				
240 Zone	135	46	20	95
271 Alvord Zone	183	38	79	83
308 Hilltop Zone[1]	133	86	119	92
339 Seattle Zone	268	31	74	115
354.5 Zone	272	36	94	113
366 Stetson Zone	234	57	174	83
368 Weiland Zone	219	65	106	114
416 Zone[2]	312	45	83	144
485 Zone	397	38	154	143
529 Zone	434	41	277	109
575 Zone	Converted to 587 Zone			
587 Zone	454	58	327	112
590 Zone	471	51	286	132
640 Zone	504	59	383	111

(1) Hydraulic grade line of the 308 Hilltop Zone measured as 332 feet in November 2017.
(2) No direct service connections exist in the 416 Zone, but the zone was included to identify pressures within the 416 Zone infrastructure.

The City is currently providing water at pressures of at least 40 psi to services in each zone except for the 271 Alvord, 339 Seattle, 354.5, 485, and 590 Zones, as shown in **Table 7-1**. The low pressures in the 339 Seattle Zone occur in the Carter Place cul-de-sac, just east of Van De Vanter Avenue. The low pressures in the 354.5 Zone occur near the intersection of Reith Road and S 253rd Street, and near the intersection of S 254th Street and 45th Avenue S. The low pressures in the 590 Zone occur within and adjacent to SE 248th Street, including portions of

121st Place SE and 120th Avenue SE near their intersections with SE 248th Street. The low pressure areas in the 590 Zone will be converted to the 640 Zone in the future, as described in **Chapter 9**.

Pressures over 120 psi occur in the 416, 485, and 590 Zones. The 416 Zone does not have any direct service connections, but the high pressures in the zone occur near the intersection of 93rd Avenue S and S 218th Street in the 16-inch-diameter transmission main between the 6 Million Gallon (MG) #1 Reservoir and the 6 MG #2 Reservoir. The high pressures in the 590 Zone occur within 100th Avenue SE, between SE 227th Street and SE 225th Place.

The proposed 20-year planning period static pressures are shown in the bottom section of **Table 7-1**. These static pressures assume that the pressure zone improvement projects described in **Chapter 9** are completed, and that services located on or near the boundary of two pressure zones are connected to the pressure zone that provides more suitable pressures.

SOURCE CAPACITY EVALUATION

This section evaluates the combined capability of the City's existing sources to determine if they have sufficient capacity to meet the overall demands of the water service area based on existing and future water demands. The section that follows will address the evaluation of the individual facilities to determine if they have sufficient capacity to meet the existing and future demands of the individual zone, or zones, that they supply.

ANALYSIS CRITERIA

Supply facilities must be capable of adequately and reliably supplying high-quality water to the system. In addition, supply facilities must provide a sufficient quantity of water at pressures that meet the requirements of Washington Administrative Code (WAC) 246-290-230. The evaluation of the combined capacity of the sources in this section is based on the criteria that they provide supply to the system at a rate that is equal to or greater than the maximum day demand (MDD) of the system.

SOURCE CAPACITY ANALYSIS RESULTS

The combined capability of the City's active sources to meet both existing and future demand requirements, based on existing pumping capacities of the individual supply facilities, is presented in **Table 7-2**. The demands used in the evaluation for 2028 and 2038 are future demand projections without reductions from water use efficiency efforts, as shown in **Table 4-12** of **Chapter 4**. Therefore, if additional reductions in water use are achieved through water use efficiency efforts, the total source capacity required in the future will be less than that shown in **Table 7-2**.

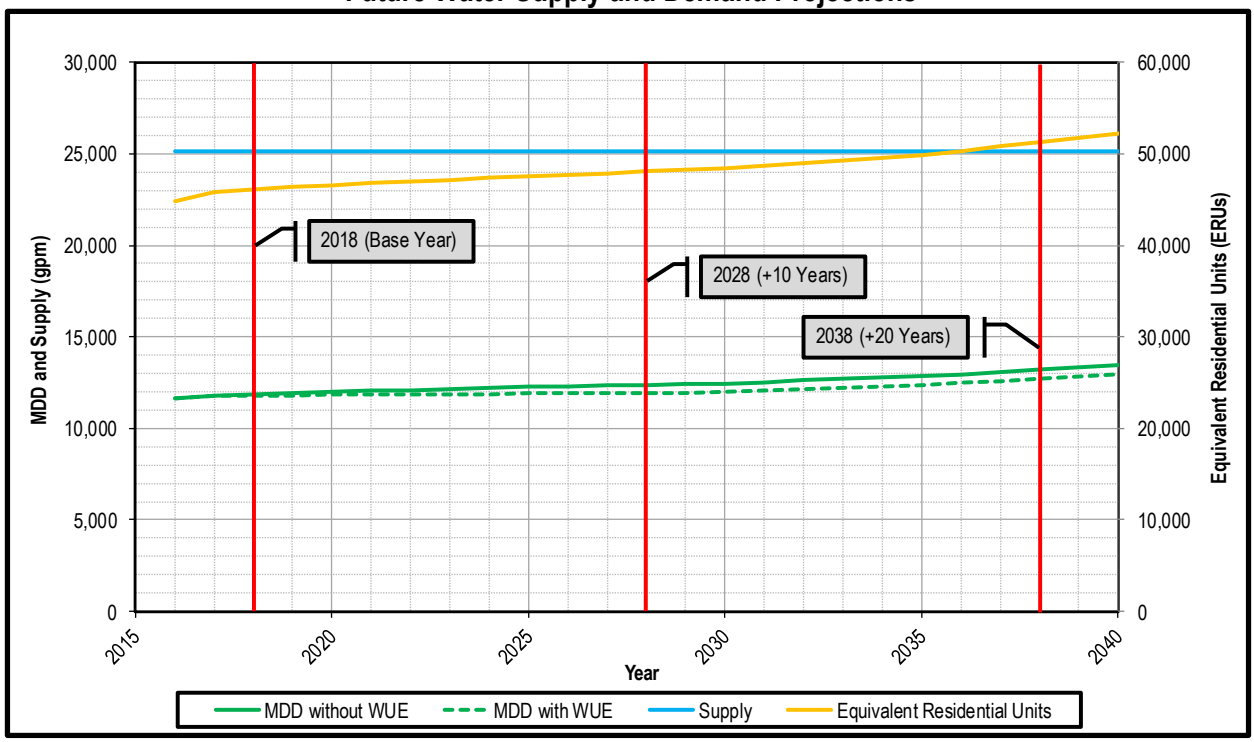
Table 7-2
Water Source Capacity Evaluation

Description	Base Year 2016	Existing 2018	Projected 2028 (+10 years)	Projected 2038 (+20 years)
Required Supply (gpm)				
Maximum Day Demand	**11,629**	**11,867**	**12,375**	**13,208**
Available Source Capacity (gpm)				
208th Street/212th Street Wellfield	3,500	3,500	3,500	3,500
Armstrong Springs Wells	1,050	1,050	1,050	1,050
Clark Springs	5,400	5,400	5,400	5,400
East Hill Well	1,900	1,900	1,900	1,900
Garrison Creek Well	500	500	500	500
Kent Springs	3,680	3,680	3,680	3,680
O'Brien Well[1]	0	0	0	0
Seven Oaks Well	350	350	350	350
Regional Water Supply System	8,778	8,778	8,778	8,778
Total Source Capacity	**25,158**	**25,158**	**25,158**	**25,158**
Surplus or Deficient Source Capacity (gpm)				
Surplus or Deficiency	**13,529**	**13,291**	**12,783**	**11,950**

(1) Currently not utilized for water quality purposes, but is equipped with pumping equipment capable of providing up to 243 gpm to the system.

The results of the analysis indicate that the City has approximately 13,530 gallons per minute (gpm) of surplus source capacity to meet existing (year 2018) demands. **Chart 7-1** shows the relationship between future projected supply and demands.

Chart 7-1
Future Water Supply and Demand Projections



WATER SUPPLY FACILITIES EVALUATION

This section evaluates the existing supply facilities to determine if they have sufficient capacity to provide water supply at a rate that meets the existing and future demands of each of the zones that they supply. **Figures 2-1** and **2-2** in **Chapter 2** display the pressure zones described within this section. This section also identifies deficiencies that are not related to the capacity of the supply facilities.

ANALYSIS CRITERIA

The evaluation to determine if supply facilities have adequate capacity is based on one of two criteria, as follows: 1) if the pressure zone that the facility provides supply into has water storage, then the amount of supply required is equal to the MDD of the zone; or 2) if the pressure zone that the facility provides supply into does not have water storage, then the amount of supply required is equal to the peak hour demand (PHD) of the zone. The higher supply requirement of the latter criteria is compensating for the lack of equalizing storage that is typically utilized to provide short-term supply during times of peak system demands.

The available supply to each pressure zone is based on the maximum pumping capacity of each facility with all pumping units operating, per the requirements of WAC 246-290-230. The

Washington State Department of Health (DOH) *Water System Design Manual* recommends that additional capacity or redundancy be considered, and that new pumping facilities be designed to provide the average day demand (ADD) of the zone with the largest pumping unit out of service. Calculations were performed for each pressure zone based on each criterion, with a description of the results provided for each pressure zone in the following sections.

SUPPLY ANALYSIS RESULTS

Valley Operating Area

240 Zone

All the City's sources are capable of directly or indirectly supplying the 240 Zone, with indirect supply from Clark Springs and the East Hill Well capable of being transferred to the 240 Zone via interties with the Kent Springs Transmission Main that supplies the 240 Zone's Guiberson Reservoir. Additionally, multiple sources, including the Armstrong Springs Wells, Seven Oaks Well, and the City's Regional Water Supply System (RWSS) Point of Delivery (POD) #3 supply either the 240 Zone via the Kent Springs Transmission Main or the East Hill operating area. For the purposes of the supply analysis, supply from the Armstrong Springs Wells and the Seven Oaks Well were assumed to be entirely available to the 240 Zone as they are not needed to meet the East Hill operating area supply requirements during normal operations. The majority of the City's total RWSS supply has historically been to the 590 Zone, with approximately 67 percent supplied to the 590 Zone in 2016 compared to approximately 33 percent supplied to the 240 Zone in 2016. The 2016 RWSS supply percentages have been assumed to be applicable for the 2018, 2028, and 2038 planning periods.

Table 7-3 summarizes the current and future supply requirements of the 240 Zone based on existing and projected water demands for the operating area. **Table 7-3** also summarizes the amount of water supply available to the 240 Zone, assuming supply from Clark Springs and the East Hill Well is exclusively conveyed to other zones and is not available to the 240 Zone. The results of the analyses indicate that the existing and proposed configurations and capacities of the 240 Zone facilities are sufficient to meet both existing and future demands. In the event that the 240 Zone's largest source (Kent Springs) is out of service, the remaining facilities have sufficient capacity to meet projected MDD of the 240 Zone beyond the 10-year planning period. If the O'Brien Well is considered available to the system, the City's supply facilities have sufficient capacity to meet projected MDD of the 240 Zone through the 20-year planning period in the event that Kent Springs is out of service.

Table 7-3
240 Zone Supply Evaluation

Description	Base Year 2016	Existing 2018	Projected 2028 (+10 years)	Projected 2038 (+20 years)
Required Supply (gpm)				
240 Zone MDD	6,676	6,813	7,069	7,685
Other Zones MDD[1]	777	792	831	847
Total Required Supply	**7,452**	**7,605**	**7,900**	**8,532**
Available Supply Capacity (gpm)				
208th Street/212th Street Wellfield	3,500	3,500	3,500	3,500
Armstrong Springs Wells[2]	1,050	1,050	1,050	1,050
Garrison Creek Well	500	500	500	500
Kent Springs	3,680	3,680	3,680	3,680
O'Brien Well[3]	0	0	0	0
Seven Oaks Well[2]	350	350	350	350
Regional Water Supply System[4]	2,926	2,926	2,926	2,926
Total Supply Capacity	**12,006**	**12,006**	**12,006**	**12,006**
Surplus or Deficient Supply Capacity (gpm)				
Surplus or Deficiency	**4,554**	**4,401**	**4,106**	**3,474**

(1) The MDD of the West Hill zones is included in the 240 Zone supply evaluation. Demands in excess of these zone's MDD (i.e., PHD or fire flow) are supplied by the 240 Zone Reservoirs.

(2) Supply from these facilities also can be conveyed to the Clark Springs Transmission Main.

(3) Currently not utilized for water quality purposes but is equipped with pumping equipment capable of providing up to 243 gpm to the system.

(4) The City's portion of the available RWSS capacity is 12.64 MGD (8,778 gpm), with water being supplied to the 240 Zone (via the Kent Springs Transmission Main) or the 590 Zone. RWSS supply is provided at two delivery points; POD #1, which conveys supply directly to the 240 Zone; and POD #3, which can supply either the 240 Zone or the 590 Zone. The majority of the City's total RWSS supply historically has been to the 590 Zone. In 2016, approximately 67 percent of the City's RWSS supply was conveyed to the 590 Zone, with approximately 33 percent of the RWSS supply conveyed to the 240 Zone. For the purposes of these analyses, 67 percent of the City's RWSS capacity was assumed to be available in the 590 Zone, with the remaining 33 percent available in the 240 Zone.

West Hill Operating Area

All water supply to the West Hill operating area currently is provided by Pump Station #3. It is expected that a future booster pump station (BPS) adjacent to S 228th Street just east of the Green River will be constructed by 2028 and will provide additional redundancy and an additional 1,000 gpm of firm capacity to the West Hill operating area. This alone is more than sufficient

capacity to meet the projected 20-year MDD of the West Hill operating area. The future BPS is anticipated to pump 240 Zone water to the 587 Zone, and is expected to be the West Hill operating area's primary supply in the future. The proposed West Hill operating area supply improvements are described in additional detail in **Chapter 9**.

354.5 Zone

All water supply to the West Hill operating area is currently provided by Pump Station #3, which pumps 240 Zone water directly to the 354.5 Zone. Pump Station #3 is currently required to supply the MDD of the 354.5 Zone, as well as the MDD of the 529, 575, and 587 Zones, which are supplied via subsequent pump stations downstream of the 354.5 Zone. It is anticipated that additional supply will be available to the 354.5 Zone in future planning periods following completion of a future West Hill BPS via pressure reducing valves from other West Hill operating area zones. **Table 7-4** summarizes the current and future supply requirements of the 354.5 Zone based on existing and projected water demands for the operating area. **Table 7-4** also summarizes the amount of water supply available to the 354.5 Zone. The results of the analyses indicate that the existing and proposed configurations and capacities of the 354.5 Zone facilities are sufficient to meet both existing and future demands. In the event that one of the Pump Station #3 pumps is out of service, the remaining pump has sufficient capacity to meet the 2016 and 2018 MDD of the operating area. Following completion of the proposed West Hill BPS, the available supply capacity to the 354.5 Zone will be sufficient to meet the projected 20-year MDD of the operating area in the event that either Pump Station #3 or the proposed West Hill BPS are out of service.

Table 7-4

354.5 Supply Evaluation

Description	Base Year 2016	Existing 2018	Projected 2028 (+10 years)	Projected 2038 (+20 years)
Required Supply (gpm)				
354.5 Zone MDD	98	100	117	120
Other Zones MDD[1,2]	678	692	0	0
Total Required Supply	**777**	**792**	**117**	**120**
Available Supply Capacity (gpm)				
Pump Station #3 - Pump 1	900	900	900	900
Pump Station #3 - Pump 2	900	900	900	900
529 to 354.5 Zone PRVs[3]	0	0	286	273
Total Supply Capacity	**1,800**	**1,800**	**2,086**	**2,073**
Surplus or Deficient Supply Capacity (gpm)				
Surplus or Deficiency	**1,023**	**1,008**	**1,969**	**1,953**

(1) The MDD of the 529, 575, and 587 Zones is included in the 2016 and 2018 supply evaluation for the 354.5 Zone. Demands in excess of these zone's MDD (i.e., PHD or fire flow) are supplied by the Reith Road Standpipe.

(2) The proposed West Hill BPS will supply the other West Hill pressure zones in 2028 and 2038; therefore, these zones will not require supply to be conveyed via the 354.5 Zone and Pump Station #3.

(3) The 2028 and 2038 supply capacity available via PRVs is the difference between the proposed 1,000 gpm West Hill BPS firm capacity and the MDD of the 529 and 587 Zones.

529 Zone

The 529 Zone currently is supplied exclusively by Pump Station #4, which pumps 354.5 Zone water to the 529 Zone. Pump Station #4 currently is required to supply the MDD of the 529 Zone, as well as the MDD of the 575 and 587 Zones, which are supplied via subsequent pump stations that pump out of the 529 Zone. It is anticipated that additional supply will be available to the 529 Zone in future planning periods following completion of a future West Hill BPS via PRVs from the 587 Zone. **Table 7-5** summarizes the current and future supply requirements of the 529 Zone based on existing and projected water demands for the operating area. **Table 7-5** also summarizes the amount of water supply available to the 529 Zone. The results of the analyses indicate that the existing and proposed configurations and capacities of the 529 Zone facilities are sufficient to meet both existing and future demands. However, sufficient fire flow is not available throughout the existing 529 Zone, as presented in the **Storage Analysis Results** section of this chapter. The proposed West Hill operating area supply improvements described in additional detail in **Chapter 9** will resolve the existing zone-wide fire flow supply deficiency in the 529 Zone.

Table 7-5
529 Supply Evaluation

Description	Base Year 2016	Existing 2018	Projected 2028 (+10 years)	Projected 2038 (+20 years)
Required Supply (gpm)				
529 Zone MDD	320	327	336	342
Other Zones MDD[1,2]	358	365	117	120
Total Required Supply	**678**	**692**	**454**	**462**
Available Supply Capacity (gpm)				
Pump Station #4 - Pump 1	900	900	900	900
Pump Station #4 - Pump 2	900	900	900	900
Pump Station #4 - Pump 3	2,000	2,000	2,000	2,000
587 to 529 Zone PRVs[3]	0	0	622	615
Total Supply Capacity	**3,800**	**3,800**	**4,422**	**4,415**
Surplus or Deficient Supply Capacity (gpm)				
Surplus or Deficiency	**3,122**	**3,108**	**3,969**	**3,953**

(1) The MDD of the 575 and 587 Zones is included in the 529 Zone supply evaluation for 2016 and 2018. Demands in excess of the 575 and 587 Zone's MDD (i.e., PHD or fire flow) are supplied by the Cambridge Tank.

(2) The MDD of the 354.5 Zone is included in the 529 Zone supply evaluation for 2028 and 2038. Following construction of the proposed West Hill BPS, the primary supply to the 354.5 Zone will be from PRVs between the 529 and 354.5 Zones.

(3) The 2028 and 2038 supply capacity available via PRVs is the difference between the proposed 1,000 gpm West Hill BPS firm capacity and the MDD of the 587 Zone.

In the event that any of the Pump Station #4 pumps are out of service, the remaining pumps have sufficient capacity to meet the 2016 and 2018 MDD of the operating area. Following completion of the proposed West Hill BPS, the available supply capacity to the 529 Zone will be sufficient to meet the projected 20-year MDD of the operating area in the event that either Pump Station #4 or the proposed West Hill BPS are out of service.

575 Zone

The 575 Zone is a closed pressure zone currently provided normal supply by Pump Station #7, which pumps 529 Zone water to the 575 Zone. During fire or emergency events wherein Pump Station #7 pumps more than 450 gpm for 3 minutes, Pump Station #7 shuts down and the 575 Zone converts to the 529 Zone, with supply conveyed to the 575 Zone customers from the 529 Zone via a check valve in Pump Station #7. **Table 7-6** summarizes the current and future supply requirements of the 575 Zone based on existing and projected water demands for the operating area. **Table 7-6** also summarizes the amount of water supply available to the 575 Zone. The results of the analyses indicate that the existing and proposed configurations and capacities

of the 575 Zone facilities are sufficient to meet both existing and future PHDs. However, sufficient fire flow is not available throughout the existing 575 Zone, as presented in the **Storage Analysis Results** section of this chapter. It is anticipated that the 575 Zone will be converted to the 587 Zone in future planning periods and will be supplied directly by a future West Hill Reservoir. The supply evaluation presented in **Table 7-6** is based on the 575 Zone remaining a closed zone (and not being converted to the 587 Zone), for conservatism, and in the event that the conversion to the 587 Zone is delayed. The proposed West Hill operating area supply improvements described in additional detail in **Chapter 9** will resolve the existing fire flow supply deficiency in the 575 Zone.

Table 7-6

575 Supply Evaluation

	Base Year	Existing	Projected	
Description	**2016**	**2018**	**2028 (+10 years)**	**2038 (+20 years)**
Required Supply (gpm)				
575 Zone PHD	88	89	94	97
575 Zone Maximum Fire Flow[1]	---	---	---	---
Total Required Supply	**88**	**89**	**94**	**97**
Available Supply Capacity (gpm)				
Pump Station #7 - Pump 1[2]	0	0	0	0
Pump Station #7 - Pump 2	250	250	250	250
Pump Station #7 - Pump 3	250	250	250	250
Largest Pump Out of Service[3]	(250)	(250)	(250)	(250)
Total Supply Capacity	**250**	**250**	**250**	**250**
Surplus or Deficient Supply Capacity (gpm)				
Surplus or Deficiency	**162**	**161**	**156**	**153**

(1) Fire flow is currently provided by the 529 Zone; therefore, it is not included in the 575 Zone supply evaluation. Fire flow in future planning periods will be provided by a future West Hill BPS and reservoir in the 587 Zone; therefore, it is not included in the 575 Zone supply

(2) Pump 1 was removed from service in 2009.

(3) DOH *Water System Design Manual* 10.1.2 recommends that at least 30 psi be provided during PHDs in a closed zone with the largest capacity booster pump out of service.

587 Zone

The 587 Zone currently is a closed pressure zone provided normal supply by Pump Station #6, which pumps 529 Zone water to the 587 Zone. During fire or emergency events wherein Pump Station #6 pumps more than 1,220 gpm for 2 minutes, Pump Station #6 shuts down and the 587 Zone converts to the 529 Zone, with supply conveyed to 587 Zone customers via two check valves from the 529 Zone. It is anticipated that additional supply will be available to the 587 Zone in the 10- and 20-year planning periods following completion of a future West Hill

BPS. A future 587 Zone reservoir is also anticipated to be constructed, providing additional redundancy to the 587 Zone and the West Hill operating area. Following completion of a future 587 Zone reservoir, the 587 Zone will not be considered a closed zone, and the 587 Zone supply facilities will be required to supply the MDD of the 587 Zone with all pumps operational, instead of the current requirement of supplying the PHD of the zone with the largest capacity booster pump out of service. It is anticipated that the primary West Hill operating area supply in future planning periods will be the future West Hill BPS; therefore, the MDD of the other West Hill pressure zones is included in the supply requirements for the future planning periods.

Table 7-7 summarizes the current and future supply requirements of the 587 Zone based on existing and projected water demands for the operating area. **Table 7-7** also summarizes the amount of water supply available to the 587 Zone. The results of the analyses indicate that the existing and proposed configurations and capacities of the 587 Zone facilities are sufficient to meet both existing and future domestic demands. However, sufficient fire flow is not available throughout the existing 587 Zone, as presented in the **Storage Analysis Results** section of this chapter. The proposed West Hill operating area supply improvements described in additional detail in **Chapter 9** will resolve the existing fire flow supply deficiency in the 587 Zone.

Table 7-7
587 Supply Evaluation

Description	Base Year 2016	Existing 2018	Projected 2028 (+10 years)	Projected 2038 (+20 years)
Required Supply (gpm)				
587 Zone MDD	---	---	378	385
587 Zone PHD	435	444	---	---
587 Zone Maximum Fire Flow[1]	---	---	---	---
Other Zones MDD	---	---	454	462
Total Required Supply	**435**	**444**	**831**	**847**
Available Supply Capacity (gpm)				
Pump Station #6 - Pump 1	200	200	200	200
Pump Station #6 - Pump 2	450	450	450	450
Pump Station #6 - Pump 3	550	550	550	550
Pump Station #8 (HWD Intertie)[2]	---	---	---	---
Largest Pump Out of Service[3]	(550)	(550)	0	0
Future West Hill BPS Firm Capacity	---	---	1,000	1,000
Total Supply Capacity	**650**	**650**	**2,200**	**2,200**
Surplus or Deficient Supply Capacity (gpm)				
Surplus or Deficiency	**215**	**206**	**1,369**	**1,353**

(1) Fire flow is currently provided by the 529 Zone; therefore, it is not included in the 587 Zone supply evaluation. Fire flow in future planning periods will be provided by a future West Hill reservoir in the 587 Zone, and is not included in the 587 Zone supply evaluation.

(2) Pump Station #8 is used in emergency situations to pump water from Highline Water District to the 587 Zone and other West Hill Zones. Pump Station #8 consists of three identical 400 gpm pumps equipped with VFDs, but is not included in the 587 Zone supply evaluation because the facility is used only when Pump Station #6 is out of service.

(3) DOH *Water System Design Manual* 10.1.2 recommends that at least 30 psi be provided during PHDs in a closed zone with the largest capacity booster pump out of service. The largest pump was not assumed to be out of service in future planning periods wherein a future 587 Zone West Hill reservoir is constructed and the 587 Zone is no longer a closed pressure zone.

East Hill Operating Area

Water supply to the East Hill operating area currently is provided by multiple sources directly to the 416 and 590 Zones, with the supply to the other East Hill pressure zones conveyed by Pump Station #5 and multiple PRVs. The easterly portion of the existing 590 Zone is expected to be converted to a 640 Zone prior to 2028; therefore, a 640 Zone supply analysis is included within this section. The proposed 640 Zone creation improvements are described in additional detail in **Chapter 9**.

The Armstrong Springs Wells, Seven Oaks Well, and RWSS POD #3 can supply either the 240 Zone via the Kent Springs Transmission Main or the East Hill operating area. For the purposes of the supply analysis, supply from the Armstrong Springs Wells and the Seven Oaks Well were assumed to be entirely available to the 240 Zone because RWSS POD #3 and other supply facilities are capable of supplying the East Hill operating area and have sufficient capacity to meet the existing and projected supply requirements of the East Hill operating area without supply from the Armstrong Springs Wells and the Seven Oaks Well. The majority of the City's total RWSS supply historically has been to the 590 Zone, with approximately 67 percent supplied to the 590 Zone in 2016 compared to approximately 33 percent supplied to the 240 Zone in 2016. The 2016 RWSS supply percentages have been assumed to be applicable for the 2018, 2028, and 2038 planning periods.

416 Zone

The 416 Zone does not have any direct service connections but includes the 6 MG #1 Reservoir which serves as the termination point of the Clark Springs Transmission Main. Water stored in the 6 MG #1 Reservoir may be pumped to the 485 Zone or 590 Zone by Pump Station #5. Water pumped to the 485 Zone is stored in the 125K Tank, is consumed by customers within the 485 Zone, and is conveyed to five zones each supplied by a single PRV station (271 Alvord, 308 Hilltop, 339 Seattle, 366 Stetson, and 368 Weiland Zones). The 416 Zone supply analysis considers the combined MDD of these pressure zones.

Supply from the Armstrong Springs Wells, Clark Springs, the Seven Oaks Well, and the 590 Zone (via a normally closed valve at the 114th Street valve station) can be conveyed to the 416 Zone in the Clark Springs Transmission Main. Supply from the 590 Zone can also be conveyed to the 416 Zone through a bypass valve in the Pump Station #5 pump manifold. For the purposes of these analyses, supply from the Armstrong Springs Wells, the Seven Oaks Well, and the 590 Zone were assumed to be entirely available to the 240 Zone because the supply capacity of Clark Springs is sufficient to meet the combined MDD of the pressure zones supplied by the 416 Zone. In the event that the Clark Springs source is out of service or is otherwise unable to supply the 416 Zone, supply from the Armstrong Springs Wells and the Seven Oaks Well is capable of supplying the 416 Zone.

Table 7-8 summarizes the current and future supply requirements of the 416 Zone based on existing and projected water demands for the zone. **Table 7-8** also summarizes the current and future amount of water supply available to the 416 Zone. The results of the analyses indicate that the existing and proposed configurations are of sufficient capacity to meet both existing and future demands.

Table 7-8
416 Zone Supply Evaluation

Description	Base Year 2016	Existing 2018	Projected 2028 (+10 years)	Projected 2038 (+20 years)
Required Supply (gpm)				
416 Zone MDD[1]	0	0	0	0
Other Zones MDD[2]	467	476	554	630
Total Required Supply	**467**	**476**	**554**	**630**
Available Supply Capacity (gpm)				
Armstrong Springs Wells[3]	0	0	0	0
Clark Springs	5,400	5,400	5,400	5,400
Seven Oaks Well[3]	0	0	0	0
590 Zone Intertie at 114th Street Valve Station	0	0	0	0
Total Supply Capacity	**5,400**	**5,400**	**5,400**	**5,400**
Surplus or Deficient Supply Capacity (gpm)				
Surplus or Deficiency	**4,933**	**4,924**	**4,846**	**4,770**

(1) No direct service connections exist within the 416 Zone. Water stored in, and supplied to, the 416 Zone is conveyed to other pressure zones via Pump Station #5 and the transmission main to the Garrison Creek (6 MG #2) Reservoir.

(2) The MDD of the 271 Alvord, 308 Hilltop, 339 Seattle, 366 Stetson, 368 Weiland, and 485 Zones are included in the 416 Zone supply evaluation. Demands in excess of these zone's MDD (i.e., PHD or fire flow) are supplied by the 125K Tank in the 485 Zone.

(3) Supply from the Armstrong Springs Wells and the Seven Oaks Well were assumed to be entirely available to the 240 Zone.

485 Zone

The 485 Zone is primarily supplied by Pump Station #5, with supplemental supply provided from the 590 Zone via multiple PRV stations. During normal operations, the Pump Station #5 small pumps (Pumps 1 and 2) supply the 485 Zone. Pump 2 is a dual speed pump that is also capable of supplying the 590 Zone. Pump Station #5 is required to supply the MDD of the 485 Zone, as well as the MDD of the 271 Alvord, 308 Hilltop, 339 Seattle, 366 Stetson, and 368 Weiland Zones, which are supplied via subsequent PRV stations. **Table 7-9** summarizes the current and future supply requirements of the 485 Zone based on existing and projected water demands for the zone. **Table 7-9** also summarizes the amount of water supply available to the 485 Zone. The results of the analyses indicate that the existing and proposed configurations and capacities of the 485 Zone facilities are sufficient to meet both existing and future MDDs, with and without the largest pumping unit in service.

Table 7-9
485 Zone (Open System) Supply Evaluation

Description	Base Year 2016	Existing 2018	Projected 2028 (+10 years)	Projected 2038 (+20 years)
Required Supply (gpm)				
485 Zone MDD	404	412	463	513
Other Zones MDD[1]	63	64	91	117
Total Required Supply	**467**	**476**	**554**	**630**
Available Supply Capacity (gpm)				
Pump Station #5 - Pump 1	1,225	1,225	1,225	1,225
Pump Station #5 - Pump 2	1,225	1,225	1,225	1,225
Pump Station #5 - Pump 3 [2]	0	0	0	0
Pump Station #5 - Pump 4 [2]	0	0	0	0
590 to 485 Zone PRVs[3]	6,750	6,750	6,750	6,750
Total Supply Capacity	**9,200**	**9,200**	**9,200**	**9,200**
Surplus or Deficient Supply Capacity (gpm)				
Surplus or Deficiency	**8,733**	**8,724**	**8,646**	**8,570**

(1) The MDD of the 271 Alvord, 308 Hilltop, 339 Seattle, 366 Stetson, and 368 Weiland Zones are included in the 485 Zone supply evaluation. Demands in excess of these zone's MDD (i.e., PHD or fire flow) are supplied by the 125K Tank.

(2) Pump Station #5 large pumps supply the 590 Zone and are unavailable to provide direct supply to the 485 Zone.

(3) Surplus supply available in the 590 Zone presented as available to the 485 Zone, up to the maximum physical capacity of the PRVs, which is calculated to be 5,400 gpm based on the maximum suggested intermittent flow through three 6-inch-diameter Cla-Val 90-01 PRVs.

As presented in the **Storage Analysis Results** section of this chapter, the only direct storage facility in the 485 Zone is the 125K Tank, which does not have sufficient capacity to meet the storage needs of the 485 Zone and subsequent zones via PRVs. A closed system supply evaluation for the 485 Zone is shown in **Table 7-10**, which indicates that sufficient supply from the 590 Zone can be conveyed to the 485 Zone via PRVs in the event that the 125K Tank and the Pump Station #5 small pumps (Pumps 1 and 2) are offline to meet the existing and future demands of the 485 Zone.

Table 7-10
485 Zone (Closed System) Supply Evaluation

Description	Base Year 2016	Existing 2018	Projected 2028 (+10 years)	Projected 2038 (+20 years)
Required Supply (gpm)				
485 Zone PHD	590	602	677	749
Other Zones PHD[1]	92	94	133	171
Maximum Fire Flow Requirement[2]	3,282	3,282	3,282	3,282
Total Required Supply	**3,964**	**3,978**	**4,091**	**4,203**
Available Supply Capacity (gpm)				
Pump Station #5 - Pump 1	0	0	0	0
Pump Station #5 - Pump 2	0	0	0	0
Pump Station #5 - Pump 3 [3]	0	0	0	0
Pump Station #5 - Pump 4 [3]	0	0	0	0
590 to 485 Zone PRVs[4]	6,750	6,750	6,750	6,750
Total Supply Capacity	**6,750**	**6,750**	**6,750**	**6,750**
Surplus or Deficient Supply Capacity (gpm)				
Surplus or Deficiency	**2,786**	**2,772**	**2,659**	**2,547**

(1) The PHD of the 271 Alvord, 308 Hilltop, 339 Seattle, 366 Stetson, and 368 Weiland Zones are included in the 485 Zone supply evaluation.

(2) Kent Hillside Church.

(3) Pump Station #5 large pumps supply the 590 Zone and are unavailable to provide direct supply to the 485 Zone.

(4) Surplus supply available in the 590 Zone presented as available to the 485 Zone, up to the maximum physical capacity of the PRVs, which is calculated to be 5,400 gpm based on the maximum suggested intermittent flow through three 6-inch-diameter Cla-Val 90-01 PRVs.

590 Zone

The 590 Zone is supplied by RWSS POD #3, the East Hill Well, and Pump Station #5. During normal operations, the Pump Station #5 small pumps (Pumps 1 and 2) supply the 485 Zone. Pump 2 is a dual speed pump that is also capable of supplying the 590 Zone. For the purposes of the supply analyses presented in this section, the Pump 2 was assumed to be unavailable to the 590 Zone. The Pump Station #5 large pumps (Pumps 3 and 4) supply the 590 Zone during normal operations.

The majority of the City's total RWSS supply has historically been to the 590 Zone, with approximately 67 percent supplied to the 590 Zone in 2016 compared to approximately 33 percent supplied to the 240 Zone in 2016. The 2016 RWSS supply percentages have been assumed to be applicable for the 2018, 2028, and 2038 planning periods. The easterly portion of the existing 590 Zone is expected to be converted to a 640 Zone prior to 2028 that will be

supplied by a future 590 to 640 Zone BPS. The 590 Zone supply requirements include the 640 Zone MDD in the future 2028 and 2038 planning periods.

Table 7-11 summarizes the current and future supply requirements of the 590 Zone based on existing and projected water demands for the zone. **Table 7-11** also summarizes the amount of water supply available to the 590 Zone. The results of the analyses indicate that the existing and proposed configurations and capacities of the 590 Zone facilities are sufficient to meet both existing and future MDDs, with and without the largest 590 Zone supply facility in service.

Table 7-11
590 Zone Supply Evaluation

Description	Base Year 2016	Existing 2018	Projected 2028 (+10 years)	Projected 2038 (+20 years)
Required Supply (gpm)				
590 Zone MDD	3,710	3,786	2,822	2,912
Other Zones MDD[1]	0	0	1,098	1,132
Total Required Supply	**3,710**	**3,786**	**3,920**	**4,045**
Available Supply Capacity (gpm)				
Pump Station #5 - Pump 1	0	0	0	0
Pump Station #5 - Pump 2 [2]	0	0	0	0
Pump Station #5 - Pump 3	1,950	1,950	1,950	1,950
Pump Station #5 - Pump 4	1,950	1,950	1,950	1,950
East Hill Well	1,900	1,900	1,900	1,900
King County WD 111 Intertie[3]	---	---	---	---
Soos Creek WSD Intertie[4]	---	---	---	---
RWSS POD #3[5]	5,852	5,852	5,852	5,852
Total Supply Capacity	**11,652**	**11,652**	**11,652**	**11,652**
Surplus or Deficient Supply Capacity (gpm)				
Surplus or Deficiency	**7,942**	**7,866**	**7,732**	**7,607**

(1) The MDD of the 640 Zone is included in the 590 Zone supply evaluation for 2028 and 2038.

(2) Pump Station #5 Pump 2 was assumed to be unavailable to the 590 Zone.

(3) The combined capacity of the three 6-inch meters that comprise the intertie with Water District 111 is 2.0 MGD. The intertie is a two-way intertie and is only used during emergency conditions; therefore it is not included in this supply capacity evaluation.

(4) The intertie has a capacity of 1.0 MGD, providing water from SCWSD's 627 Pressure Zone to the City's 590 Zone during emergency conditions; therefore it is not included in this supply capacity evaluation.

(5) The City's portion of the available RWSS capacity is 12.64 MGD (8,778 gpm), with water being supplied to the 240 Zone (via the Kent Springs Transmission Main) or the 590 Zone. RWSS supply is provided at two connection points; RWSS POD #1, which conveys supply directly to the 240 Zone; and RWSS POD #3, which can supply either the 240 Zone or the 590 Zone. The majority of the City's total RWSS supply has historically been to the 590 Zone. In 2016, approximately 67 percent of the City's RWSS supply was conveyed to the 590 Zone, with approximately 33 percent of the RWSS supply conveyed to the 240 Zone. For the purposes of these analyses, 67 percent of the City's RWSS capacity was assumed to be available in the 590 Zone, with the remaining 33 percent available in the 240 Zone.

640 Zone

The 640 Zone is expected to be created prior to the 2028 planning period and consists of the easterly portion of the existing 590 Zone. The 640 Zone will be supplied by two future 640 Zone BPSs, and the existing 640 Tank will provide water storage for the zone. One future 640 Zone BPS is planned to be constructed at the Blue Boy Standpipe site, and is anticipated to consist of three 1,750 gpm pumps, resulting in a firm capacity of 3,500 gpm with one pump out of service. The other future 640 Zone BPS is planned to be constructed at the RWSS POD #3 site, and is also anticipated to consist of three 1,750 gpm pumps, resulting in a firm capacity of 3,500 gpm with one pump out of service, and providing the future 640 Zone a redundant supply facility. **Table 7-12** summarizes the future supply requirements of the 640 Zone based on projected water demands for the zone. **Table 7-12** also summarizes the amount of water supply available to the 640 Zone. The results of the analyses indicate that the proposed configuration and capacity of one of the future 640 Zone BPSs is sufficient to meet future MDDs with the largest pumping unit out of service.

Table 7-12

640 Zone Supply Evaluation

	Base Year	Existing	Projected	
Description	**2016**	**2018**	**2028 (+10 years)**	**2038 (+20 years)**
Required Supply (gpm)				
640 Zone MDD	---	---	1,098	1,132
Other Zones MDD	---	---	0	0
Total Required Supply	**---**	**---**	**1,098**	**1,132**
Available Supply Capacity[1] (gpm)				
640 Zone BPS (Blue Boy Standpipe Site)	---	---	3,500	3,500
640 Zone BPS (RWSS POD #3 Site)	---	---	3,500	3,500
Total Supply Capacity	**---**	**---**	**7,000**	**7,000**
Surplus or Deficient Supply Capacity (gpm)				
Surplus or Deficiency	**---**	**---**	**5,902**	**5,868**

(1) Firm capacity for each BPS shown (i.e., largest pumping unit in each BPS out of service).

FACILITY DEFICIENCIES

The West Hill operating area lacks redundancy without the use of the Highline Water District Emergency Intertie, as Pump Station #3 is the only facility that supplies the West Hill operating area, and Pump Station #4 is the only facility that can supply the 529, 575, and 587 Zones. If Pump Station #4 was out of service, these zones would need to be supplied by the Highline Water District Emergency Intertie, which is limited in capacity to 1,200 gpm based on the capacity of Pump Station #8. If Pump Station #3 is out of service, the West Hill operating area could be temporarily supplied by the water stored in the Reith Road Standpipe, which has capacity to provide approximately 1.7 days of storage to the West Hill operating area during existing ADD conditions. Improvements to provide redundancy to the West Hill operating area by constructing additional facilities are described in **Chapter 9**.

The O'Brien Well is not normally operated because 480-volt power is not available at the facility and the City has to transport a generator to the site to operate the well pump, sand is present inside the well screen, and high levels of manganese are present in the groundwater. Manganese is a secondary contaminant that can stain fixtures and laundry and may lead to aesthetic customer complaints if not mitigated. **Chapter 9** identifies improvements to provide 480-volt power to the site, redevelop the well, and provide a manganese treatment facility.

STORAGE FACILITIES

This section evaluates the City's existing water storage tanks to determine if they have sufficient capacity to meet the existing and future storage requirements of the system. This section also identifies facility deficiencies that are not related to the capacity of the water tanks.

ANALYSIS CRITERIA

Water storage is typically made up of the following components: operational storage; equalizing storage; standby storage; fire flow storage; and dead storage. Each storage component serves a different purpose and will vary from system to system. A definition of each storage component and the criteria used to evaluate the capacity of the City's storage tanks is provided below.

Operational Storage – Volume of the reservoir used to supply the water system under normal conditions when the source or sources of supply are not delivering water to the system (i.e., sources are in the off mode). Operational storage is the average amount of drawdown in the reservoir during normal operating conditions, which represents a volume of storage that most likely will not be available for equalizing storage, fire flow storage, or standby storage. The operational storage is based on the amount of storage between the fill, or pump starting setpoint level, and the overflow elevation of the tank.

Equalizing Storage – Volume of the reservoir used to supply the water system under peak demand conditions when the system demand exceeds the total rate of supply of the sources. DOH requires that equalizing storage be stored above an elevation that will provide a minimum

pressure of 30 psi at all service connections throughout the system under PHD conditions. Because the City's supply sources primarily operate on a "call on demand" basis to fill the reservoirs, the equalizing storage requirements are determined with Equation 9-1 from the DOH *Water System Design Manual* that considers the difference between the system PHD and the combined capacity of the supply sources.

Equation 9-1: ES = (PHD – Q_S)(150 minutes), but in no case less than zero

Where:

ES = Equalizing Storage, in gallons

PHD = Peak Hour Demand, in gpm

Q_S = Sum of all installed and active sources, except emergency supply, in gpm.

The capacities of the sources that supply each zone are sufficient to meet the peak hour demands of their zones. Therefore, the equalizing storage requirement for each supply area is zero.

Standby Storage – Volume of the reservoir used to supply the water system under emergency conditions when supply facilities are out of service due to equipment failures, power outages, loss of supply, transmission main breaks, and any other situation that disrupts the supply source. DOH requires that standby storage be stored above an elevation that will provide a minimum pressure of 20 psi at all service connections throughout the system. The criteria for determining the standby storage requirements for the City's system, which has multiple supply sources, is based on Equation 9-3 from the DOH *Water System Design Manual*, which requires average day demand and supply source capacity data. The amount required is sufficient to supply the system for a 48-hour period when the primary supply facility is out of service and the system is experiencing average day demands.

Equation 9-3: SB = (2 days)[(ADD)(N) – t_m (Q_S – Q_L)]

Where:

SB =	Standby Storage, in gallons
ADD =	Average Day Demand per equivalent residential unit (ERU), in gallons per day (gpd) per ERU
N =	Number of ERUs
Q_S =	Sum of all installed and continuously available sources, except emergency supply, in gpm
Q_L =	The capacity of the largest source available to the system, in gpm
t_m =	Time the remaining sources are pumped on the day when the largest source is not available, in minutes. Unless otherwise restricted, this value is 1,440 minutes.

In addition to the standby storage requirements calculated from Equation 9-3, DOH recommends that the minimum standby storage volume be no less than 200 gallons per ERU.

Fire Flow Storage – Volume of the reservoir used to supply water to the system at the maximum rate and duration required to extinguish a fire at the building with the highest fire flow

requirement. The magnitude of the fire flow storage is the product of the fire flow rate and duration of the system's maximum fire flow requirement established by the local fire authority, the Puget Sound Regional Fire Authority. DOH requires that fire flow storage be stored above an elevation that will provide a minimum pressure of 20 psi at all points throughout the distribution system under MDD conditions.

The fire flow storage requirements shown in the analyses that follow are based on the maximum fire flow requirements in each pressure zone. The maximum fire flow requirement in the 240 Zone is 5,000 gpm for a 4-hour duration, which is equivalent to 1,200,000 gallons. The maximum fire flow requirement in the 354.5 Zone is 1,650 gpm for a 2-hour duration, which is equivalent to 198,000 gallons. The maximum fire flow requirement in the 529 Zone operating area and in the 587 Zone operating area is 4,600 gpm for a 4-hour duration, which is equivalent to 1,104,000 gallons. The maximum fire flow requirement in the 485 Zone is 3,282 gpm for a 4-hour duration, which is equivalent to 787,680 gallons. The maximum fire flow requirement in the 590 Zone operating area is 4,600 gpm for a 4-hour duration, which is equivalent to 1,104,000 gallons. The maximum fire flow requirement in the future 640 Zone operating area is 3,500 gpm for a 3-hour duration, which is equivalent to 630,000 gallons.

***Dead Storage* –** Volume of the reservoir that cannot be used because it is stored at an elevation that does not provide system pressures that meet the minimum pressure requirements established by DOH without pumping. This unusable storage occupies the lower portion of most ground-level reservoirs. Water that is stored below an elevation that cannot provide a minimum pressure of 20 psi is considered dead storage for the analyses that follow.

STORAGE ANALYSIS RESULTS

System-Wide Storage

The storage analyses are based on an evaluation of the existing storage facilities providing water to the City's distribution system. The maximum combined storage capacity of the City's reservoirs is 23.33 MG, as shown in **Table 7-13**. Operational storage is based on BPS setpoints provided by the City. Equalizing storage is based on the results of Equation 9-1 from the DOH *Water System Design Manual*. Standby storage is based on providing 200 gallons of storage per ERU, which is more conservative than the results of Equation 9-3 from the DOH *Water System Design Manual*. There is currently 3.76 MG of dead storage (i.e., non-usable storage) in the water system, of which 3.65 MG is within the 590 Zone. The results of the existing storage evaluation, as shown in **Table 7-13**, indicate that the existing (2018) system has a storage surplus of approximately 5.82 MG.

Table 7-13
System-Wide Storage Evaluation

Description	Base Year 2016	Existing 2018	Projected 2028 (+10 years)	Projected 2038 (+20 years)
Available/Usable Storage (MG)				
Maximum Storage Capacity	23.33	23.33	30.28	30.28
Dead (Non-usable) Storage	3.76	3.76	6.06	6.06
Total Available Storage	**19.57**	**19.57**	**24.22**	**24.22**
Required Storage (MG)				
Operational Storage	3.57	3.57	4.12	4.12
Equalizing Storage	0.00	0.00	0.00	0.00
Standby Storage	8.97	9.22	9.61	10.26
Fire Flow Storage	1.20	1.20	1.20	1.20
Total Required Storage	**13.74**	**13.99**	**14.93**	**15.58**
Surplus or Deficient Storage (MG)				
Surplus or Deficient Amount	**5.82**	**5.58**	**9.29**	**8.64**

The system's future storage requirements, also shown in **Table 7-13**, were computed for the 10- and 20-year planning periods based on the corresponding demand projections shown in **Chapter 4**. The 10- and 20-year planning periods include additional usable storage within the existing 640 Tank that will become available to the system as part of the 640 Zone conversion project, and the construction of 3.00 MG of usable storage in the West Hill operating area. The City is projected to have a system-wide storage surplus through the 20-year planning period.

Valley Operating Area

240 Zone Storage

The City's 240 Zone, which is provided storage by the 6 MG #2 and Guiberson Reservoirs, has an existing combined storage capacity of 9.00 MG, as shown in **Table 7-14**. Operational storage is based on source setpoints provided by the City. Equalizing storage is based on the results of Equation 9-1 from the DOH *Water System Design Manual*. Standby storage is based on a rate of 200 gpd per ERU in the zone, which is more conservative than the results of Equation 9-3 from the DOH *Water System Design Manual*. There is currently no dead storage (i.e., non-usable storage) in the 240 Zone. The results of the storage evaluation, as shown in **Table 7-14**, indicate that the 240 Zone storage facilities have sufficient capacity to meet the existing and future storage requirements through the 20-year planning period.

Table 7-14
240 Zone Storage Capacity Evaluation

Description	Base Year Existing 2016	Existing 2018	Projected 2028 (+10 years)	Projected 2038 (+20 years)
Available/Usable Storage (MG)				
Maximum Storage Capacity	9.00	9.00	9.00	9.00
Dead (Non-usable) Storage	0.00	0.00	0.00	0.00
Total Available Storage	**9.00**	**9.00**	**9.00**	**9.00**
Required Storage (MG)				
Operational Storage	0.49	0.49	0.49	0.49
Equalizing Storage	0.00	0.00	0.00	0.00
Standby Storage	5.15	5.29	5.49	5.97
Fire Flow Storage	1.20	1.20	1.20	1.20
Total Required Storage	**6.84**	**6.98**	**7.18**	**7.65**
Surplus or Deficient Storage (MG)				
Surplus or Deficient Amount	**2.16**	**2.02**	**1.82**	**1.35**

As presented in **Chapter 9**, the Guiberson Reservoir is proposed to be replaced within the 20-year planning period. The City is considering constructing the replacement reservoir with a larger capacity than the 3.00 MG capacity of the existing reservoir, with the proposed reservoir capacity to be identified during the predesign and design phases of the project. The storage capacity evaluation presented in **Table 7-14** assumes the Guiberson Reservoir storage volume to be 3.00 MG through the 20-year planning period, and any increase in storage volume that occurs when the Guiberson Reservoir is replaced will increase the surplus storage capacity available in the 240 Zone.

West Hill Operating Area

354.5 Zone Storage

The City's 354.5 Zone, which is provided storage by the Reith Road Standpipe, has an existing storage capacity of 1.01 MG, as shown in **Table 7-15**. Operational storage is based on BPS setpoints provided by the City. Equalizing storage is based on the results of Equation 9-1 from the DOH *Water System Design Manual*. Standby storage is based on the results of Equation 9-3 from the DOH *Water System Design Manual*, which is more conservative than a rate of 200 gpd per ERU in the zone. There is currently 0.12 MG of dead storage (i.e., non-usable storage) in the 354.5 Zone. The results of the storage evaluation, as shown in **Table 7-15**, indicate that the 354.5 Zone storage facility has sufficient capacity to meet the existing and future storage requirements through the 20-year planning period. For conservatism, the future system 354.5 Zone storage evaluation shown in **Table 7-15** does not include consideration for a future West Hill Reservoir that is proposed to be constructed in the 587 Zone to provide additional storage capacity in the West Hill operating area.

Table 7-15
354.5 Zone Storage Capacity Evaluation

Description	Base Year 2016	Existing 2018	Projected 2028 (+10 years)	Projected 2038 (+20 years)
Available/Usable Storage (MG)				
Maximum Storage Capacity	1.01	1.01	1.01	1.01
Dead (Non-usable) Storage	0.12	0.12	0.12	0.12
Total Available Storage	**0.90**	**0.90**	**0.90**	**0.90**
Required Storage (MG)				
Operational Storage	0.24	0.24	0.24	0.24
Equalizing Storage	0.00	0.00	0.00	0.00
Standby Storage	0.13	0.13	0.16	0.16
Fire Flow Storage	0.20	0.20	0.20	0.20
Total Required Storage	**0.57**	**0.57**	**0.59**	**0.60**
Surplus or Deficient Storage (MG)				
Surplus or Deficient Amount	**0.33**	**0.33**	**0.30**	**0.30**

529 Zone Storage

The City's 529 Zone, which is currently provided storage by the Cambridge Tank, has an existing storage capacity of 0.30 MG, as shown in **Table 7-16**. Operational storage is based on BPS setpoints provided by the City. Equalizing storage is based on the results of Equation 9-1 from the DOH *Water System Design Manual*. Standby storage is based the results of Equation 9-3 from the DOH *Water System Design Manual*, which is more conservative than a rate of 200 gpd per ERU in the zone. There is currently no dead storage (i.e., non-usable storage) in the 529 Zone. The Cambridge Tank currently provides fire flow storage for not only the 529 Zone, but also the 575 and 587 Zones. The results of the storage evaluation, as shown in **Table 7-16**, indicate that the Cambridge Tank does not have sufficient capacity to meet the existing and future storage requirements through the 20-year planning period. During a fire or emergency event, supply to the 529 Zone is initially provided by the Cambridge Tank, but as shown in **Table 7-16**, the Cambridge Tank capacity is significantly less than the volume required for fire flow. As the Cambridge Tank water level is reduced, Pump Station #4 is utilized to provide supply to the 529 Zone during fire or emergency events. Prior to 2028, it is expected that a new West Hill Reservoir will be constructed in the 587 Zone to provide adequate storage for the 529, 575, and 587 Zones, and improve redundancy in the West Hill operating area. The Cambridge Tank will remain operational following the completion of a future West Hill Reservoir and will be normally filled by water conveyed from the future West Hill Reservoir via a future PRV proposed to be installed at Pump Station #7.

Table 7-16
529 Zone Storage Capacity Evaluation

Description	Base Year 2016	Existing 2018	Projected[1] 2028 (+10 years)	Projected[1] 2038 (+20 years)
Available/Usable Storage (MG)				
Maximum Storage Capacity	0.30	0.30	0.30	0.30
Dead (Non-usable) Storage	0.00	0.00	0.00	0.00
Total Available Storage	**0.30**	**0.30**	**0.30**	**0.30**
Required Storage (MG)				
Operational Storage	0.16	0.16	0.16	0.16
Equalizing Storage	0.00	0.00	0.00	0.00
Standby Storage	0.90	0.92	0.95	0.96
Fire Flow Storage	1.10	1.10	1.10	1.10
Total Required Storage	**2.16**	**2.18**	**2.21**	**2.23**
Surplus or Deficient Storage (MG)				
Surplus or Deficient Amount	**(1.86)**	**(1.88)**	**(1.91)**	**(1.93)**

(1) A proposed 587 Zone West Hill reservoir will provide future system storage for the 529, 575, and 587 Zones.

587 Zone Storage

The City's 587 Zone currently does not have water storage, and adequate fire flow storage is not available in the three West Hill operating zones with the highest hydraulic grades (529, 575, and 587 Zones). A future 587 Zone reservoir is expected to be constructed prior to 2028 to improve fire flow protection and reliability in the West Hill operating area. **Table 7-17** presents the projected 2028 and 2038 storage capacity evaluation for the 587 Zone. The storage requirements of the 354.5, 529, and 575 Zones are included in the 587 Zone evaluation shown in **Table 7-17**, which indicate that the proposed 587 Zone reservoir will provide sufficient capacity to meet the existing and future storage requirements of the 587 Zone operating area, which includes the entire West Hill operating area (354.5, 529, 575, and 587 Zones), through the 20-year planning period.

Table 7-17
587 Zone Storage Capacity Evaluation

	Base Year	Existing	Projected	
Description	2016	2018	2028 (+10 years)	2038 (+20 years)
Available/Usable Storage (MG)				
Maximum Storage Capacity	---	---	5.30	5.30
Dead (Non-usable) Storage	---	---	2.30	2.30
Total Available Storage	**---**	**---**	**3.00**	**3.00**
Required Storage (MG)				
Operational Storage	---	---	0.55	0.56
Equalizing Storage	---	---	0.00	0.00
Standby Storage	---	---	0.65	0.66
Fire Flow Storage[1]	---	---	1.50	1.50
Total Required Storage	**---**	**---**	**2.70**	**2.72**
Surplus or Deficient Storage (MG)				
Surplus or Deficient Amount	**---**	**---**	**0.31**	**0.28**

(1) Existing maximum fire flow requirement in the 587 and 575 Zones is 4,600 gpm for 4 hours (Totem Middle School), resulting in a fire flow storage volume of 1.10 MG. The City anticipates redevelopment within the 587 Zone, and is planning for a future maximum fire flow requirement of 5,000 gpm for 5 hours in the 587 Zone, resulting in a fire flow storage volume of 1.50 MG.

East Hill Operating Area

590 Zone Storage

The City's 590 Zone, which is currently provided storage by the 3.5 MG Tank, the Blue Boy Standpipe, and the 640 Tank, has an existing combined storage capacity of 6.88 MG as shown in **Table 7-18**. Operational storage is based on BPS setpoints provided by the City. Equalizing storage is based on the results of Equation 9-1 from the DOH *Water System Design Manual*. Standby storage is based on a rate of 200 gpd per ERU in the zone, which is more conservative than the results of Equation 9-3 from the DOH *Water System Design Manual*. There is currently 3.65 MG of dead storage (i.e., non-usable storage) in the 590 Zone, the majority of which will be eliminated following the 640 Zone conversion project that is described in more detail in **Chapter 9**. The results of the 590 Zone storage evaluation, as shown in **Table 7-18**, indicate that the 590 Zone storage facilities do not have sufficient capacity to meet the existing storage requirements.

Table 7-18
590 Zone Storage Capacity Evaluation

Description	Base Year 2016	Existing 2018	Projected 2028 (+10 years)	Projected 2038 (+20 years)
Available/Usable Storage (MG)				
Maximum Storage Capacity	6.88	6.88	4.50	4.50
Dead (Non-usable) Storage	3.65	3.65	1.32	1.32
Total Available Storage	**3.23**	**3.23**	**3.17**	**3.17**
Required Storage (MG)				
Operational Storage	0.90	0.90	0.21	0.21
Equalizing Storage	0.00	0.00	0.00	0.00
Standby Storage	2.86	2.94	2.19	2.26
Fire Flow Storage	1.10	1.10	1.10	1.10
Total Required Storage	**4.87**	**4.95**	**3.50**	**3.57**
Surplus or Deficient Storage (MG)				
Surplus or Deficient Amount	**(1.64)**	**(1.72)**	**(0.33)**	**(0.40)**

Prior to 2028, the easterly portion of the 590 Zone is expected to be converted to a 640 Zone, which reduces the available and required storage in the 590 Zone. However, the City will be able to fill the 640 Tank to a maximum hydraulic grade of 645 feet following implementation of the 640 Zone conversion, resulting in approximately 1.65 MG of additional storage capacity. Additionally, the highest existing 590 Zone service connections will be transferred to the 640 Zone in the future, reducing the dead storage volume in the future 590 Zone storage facilities (Blue Boy Standpipe and the 3.5 MG Tank) by approximately 1.39 MG. Future surplus storage volume in the 640 Zone, presented in the **640 Zone Storage** section of this chapter, will be available to the 590 Zone via multiple PRVs to resolve the projected 10- and 20-year planning period storage deficiencies shown in **Table 7-18**.

640 Zone Storage

Storage in the 640 Zone will be provided by the existing 640 Tank, which is currently operated at a maximum hydraulic grade of 590 feet. In the future, the 640 Tank will provide 3.10 MG of usable storage to the 640 Zone and will be operated at a maximum hydraulic grade of 645 feet. **Table 7-19** presents the projected 2028 and 2038 storage evaluation for the 640 Zone, and indicates that the 640 Tank has sufficient capacity to meet the future 640 Zone storage requirements through the 20-year planning period. The projected 640 Zone storage surplus is also sufficient to resolve the projected 590 Zone storage deficiencies in the 10- and 20-year planning periods.

Table 7-19
640 Zone Storage Capacity Evaluation

Description	Base Year 2016	Existing 2018	Projected 2028 (+10 years)	Projected 2038 (+20 years)
Available/Usable Storage (MG)				
Maximum Storage Capacity	---	---	4.03	4.03
Dead (Non-usable) Storage	---	---	0.93	0.93
Total Available Storage	---	---	**3.10**	**3.10**
Required Storage (MG)				
Operational Storage	---	---	0.81	0.81
Equalizing Storage	---	---	0.00	0.00
Standby Storage	---	---	0.85	0.88
Fire Flow Storage	---	---	0.63	0.63
Total Required Storage	---	---	**2.29**	**2.32**
Surplus or Deficient Storage (MG)				
Surplus or Deficient Amount	---	---	**0.81**	**0.78**

The combined storage requirements of the 590 and 640 Zones following the 640 Zone conversion project is shown in **Table 7-20**. The combined 590 and 640 Zones storage requirements are based on the sum of the operational and standby storage volumes in the two zones. Equalizing storage is based on the results of Equation 9-1 from the DOH *Water System Design Manual*. Fire flow storage is based on the maximum planning-level fire flow requirement in the 590 and 640 Zones, which is 4,600 gpm for 4 hours based on the requirements of the Fred Meyer located on SE 240th Street, The Home Depot located on 104th Avenue SE, and Kent-Meridian High School located on SE 256th Street.

Table 7-20
Combined 590 and 640 Zone Future Storage Capacity Evaluation

Description	Base Year 2016	Existing 2018	Projected 2028 (+10 years)	Projected 2038 (+20 years)
Available/Usable Storage (MG)				
Maximum Storage Capacity	---	---	8.53	8.53
Dead (Non-usable) Storage	---	---	2.26	2.26
Total Available Storage	---	---	**6.27**	**6.27**
Required Storage (MG)				
Operational Storage	---	---	1.02	1.02
Equalizing Storage	---	---	0.00	0.00
Standby Storage	---	---	3.04	3.14
Fire Flow Storage	---	---	1.10	1.10
Total Required Storage	---	---	**5.16**	**5.26**
Surplus or Deficient Storage (MG)				
Surplus or Deficient Amount	---	---	**1.11**	**1.01**

485 Zone Storage

The City's 485 Zone, which is provided direct storage by the 125K Tank, has an existing storage capacity of 0.13 MG. The City's 6 MG #1 Reservoir provides indirect storage to the 485 Zone via Pump Station #5, which pumps from the 6 MG #1 Reservoir to the 125K Tank and the 485 Zone. As described in the **Supply Analysis Results** section of this chapter and shown in **Table 7-10**, the City can utilize Pump Station #5 to provide supply to the 485 Zone during peak demand and emergency demand conditions. Therefore, the combined storage capacity of the 125K Tank and the 6 MG #1 Reservoir, 6.14 MG, is considered in the 485 Zone storage capacity evaluation shown in **Table 7-21**. Operational storage is based on BPS setpoints provided by the City. Equalizing storage is based on the results of Equation 9-1 from the DOH *Water System Design Manual*, with demands in Equation 9-1 equivalent to the maximum pumping capacity of Pump Station #5 to represent the maximum conveyance out of the 6 MG #1 Reservoir, and a supply rate equivalent to the Clark Springs capacity. Standby storage is based on a rate of 200 gpd per ERU in the zone, which is more conservative than the results of Equation 9-3 from the DOH *Water System Design Manual*. There is currently no dead storage (i.e., non-usable storage) in either reservoir. The results of the 485 Zone storage evaluation, as shown in **Table 7-21**, indicate that the 125K Tank and the 6 MG #1 Reservoir have sufficient capacity to meet the existing and future storage requirements of the 485 Zone through the 20-year planning period.

Table 7-21
485 Zone Storage Capacity Evaluation

Description	Base Year 2016	Existing 2018	Projected 2028 (+10 years)	Projected 2038 (+20 years)
Available/Usable Storage (MG)				
485 Zone Maximum Storage Capacity	6.14	6.14	6.14	6.14
485 Zone Dead (Non-usable) Storage	0.00	0.00	0.00	0.00
Total Available Storage	**6.14**	**6.14**	**6.14**	**6.14**
Required Storage (MG)				
Operational Storage	1.99	1.99	1.99	1.99
Equalizing Storage	0.23	0.23	0.23	0.23
Standby Storage	0.36	0.37	0.43	0.49
Fire Flow Storage	0.79	0.79	0.79	0.79
Total Required Storage	**3.37**	**3.38**	**3.44**	**3.50**
Surplus or Deficient Storage (MG)				
Surplus or Deficient Amount	**2.77**	**2.76**	**2.70**	**2.64**

FACILITY DEFICIENCIES

In order to resolve the storage deficiency in the West Hill operating area (as shown within the **529 Zone Storage** evaluation), a new 587 Zone reservoir will be constructed in the West Hill area. The City is considering a currently undeveloped property on the West Hill between 38th Avenue S and Military Road S, adjacent to S 248th Street. Construction of a new 587 Zone reservoir is described in **Chapter 9**.

In order to resolve the storage deficiency in the City's 590 Zone, the City is converting the easterly portion of the 590 Zone to a 640 Zone, which reduces the available and required storage in the 590 Zone. The City will be able to fill the 640 Tank to a maximum hydraulic grade of 645 feet following implementation of the 640 Zone conversion (currently, the maximum hydraulic grade of the 640 Tank is 590 feet), resulting in approximately 1.65 MG of additional storage capacity. Additionally, the highest existing 590 Zone service connections will be transferred to the 640 Zone in the future, reducing the dead storage volume in the future 590 Zone storage facilities by approximately 1.39 MG. The resulting storage evaluation for the combined 590 and 640 Zones indicates sufficient capacity will be available in the storage facilities to meet the requirements through the 20-year planning period.

The City's 2016 sanitary survey identified the need to retrofit or replace the air vents on the 6 MG #1 Reservoir, 125K Tank, Blue Boy Standpipe, Cambridge Tank, and the Reith Road Standpipe. The Cambridge Tank retrofit has been completed, and the 125K Tank retrofit is being designed in 2018 with construction planned for 2019. The retrofits for the remaining three tanks are scheduled to be completed by 2021, as identified in **Chapter 9**.

DISTRIBUTION AND TRANSMISSION SYSTEM

This section evaluates the City's existing distribution and transmission system (i.e., water mains) to determine if they are adequately sized and looped to provide the necessary flow rates and pressures to meet the existing and future requirements of the system. This section also identifies deficiencies that are not related to the capacity of the water mains.

ANALYSIS CRITERIA

Distribution and transmission mains must be capable of adequately and reliably conveying water throughout the system at acceptable flow rates and pressures. The criteria used to evaluate the City's distribution and transmission system are the state mandated requirements for Group A water systems contained in WAC 246-290-230 – Distribution Systems. The pressure analysis criteria state that the distribution system "…shall be designed with the capacity to deliver the design PHD quantity of water at 30 psi under PHD flow conditions measured at all existing and proposed service water meters." It also states that if fire flow is to be provided, "… the distribution system shall also provide MDD plus the required fire flow at a pressure of at least 20 psi at all points throughout the distribution system."

Hydraulic analyses of the existing system were performed under existing PHD conditions to evaluate its current pressure capabilities and identify existing system deficiencies. The existing system also was analyzed under existing MDD conditions to evaluate the current fire flow capabilities and identify additional existing system deficiencies. Additional hydraulic analyses were then performed with the same hydraulic model under future PHD and MDD conditions and with the proposed improvements to demonstrate that the identified improvements will eliminate the deficiencies and meet the requirements far into the future. The following is a description of the hydraulic model, the operational conditions, and facility settings used in the analyses.

HYDRAULIC MODEL

Description

A computer-based hydraulic model of the existing water system was updated to the CONNECT edition of the WaterGEMS® program (developed by Bentley Systems, Inc.) with the City's most recent Geographic Information System (GIS) shapefile to reflect the best-known information on distribution system geometry and pipe characteristics, including diameter, material, and installation year.

Hydraulic model pipe roughness coefficients were initialized with computed estimates based on the water main material and age information from the City's water main GIS shapefile. Based on the premise that the internal surface of water mains become rougher as they get older, older water mains were assigned higher roughness coefficients than newer water mains. The junction node elevation data were updated using King County provided 5-foot contour data. A hydraulic model

node diagram, providing a graphical representation of the model of the water system, is contained in **Appendix L**.

Demand Data

The hydraulic model of the existing system contains demands based on 2016 individual customer meter water demand data provided by the City. Demand data for each parcel was distributed to the closest representative junction node of the model based on the recorded usage, which was then uniformly scaled to simulate the 2016 MDD and PHD. The peaking factors calculated in **Chapter 4** were used to analyze the system under PHD and MDD conditions.

The hydraulic model of the proposed system contains 10-year demand levels that are projected for the year 2028, and 20-year demand levels that are projected for the year 2038.

The future demand distribution is based on planning area estimates identified in **Chapter 3**, which include population projections in Traffic Analysis Zones (TAZ) and employment projections in census tracts provided by the Puget Sound Regional Council (PSRC). The resulting ADD allocation for each pressure zone is shown in **Table 7-22**.

Table 7-22
Pressure Zone Demand Allocation

	ADD (gpm)			
Pressure Zone	2016 (Base)	2018 (Existing)	2028 (+10 years)	2038 (+20 years)
240	3,070	3,133	3,251	3,534
271 Alvord	12	12	16	20
308 Hilltop	0.4	0.4	1	1
339 Seattle	11	11	18	23
354.5	45	46	54	55
366 Stetson	2	2	3	3
368 Weiland	3	3	5	6
416	0.0	0.0	0.0	0.0
485	186	189	213	236
529	147	150	155	157
575	28	28	30	31
587	137	140	144	146
590	1,706	1,741	1,298	1,339
640	0.0	0.0	505	521
Total	**5,348**	**5,458**	**5,691**	**6,074**

Facilities

The hydraulic model of the existing system contains all active, existing system facilities. For the proposed system analyses in the year 2028 and 2038, the hydraulic model contains all active existing system facilities and proposed system improvements identified in **Chapter 9** for the 10- and 20-year planning periods, respectively.

The facility settings for the pressure analyses corresponded to a PHD event in the water system. All sources of supply that currently are available to the system or will be available in the future for the years 2028 and 2038 analyses, during a peak period were operating at their normal summertime pumping rates. The reservoir levels were modeled to reflect full utilization of operational and equalizing storage. The operational conditions for the pressure analyses are summarized in **Table 7-23**.

Table 7-23

Hydraulic Analyses Operational Conditions

	PHD Pressure Analyses			Fire Flow Analyses		
Description	**2016**	**2028 (+10 years)**	**2038 (+20 years)**	**2016**	**2028 (+10 years)**	**2038 (+20 years)**
Demand	2016 PHD	2028 PHD	2038 PHD	2016 MDD	2028 MDD	2038 MDD
Storage Facilities HGL (feet)						
Garrison Creek Reservoir	237.75	237.75	237.75	234.53	234.53	234.53
Guiberson Reservoir	236.50	236.50	236.50	233.28	233.28	233.28
Reith Road Standpipe	345.20	345.20	345.20	337.46	337.46	337.46
6 MG #1 Reservoir	404.00	404.00	404.00	404.00	404.00	404.00
125K Tank	456.31	456.31	456.31	463.51	463.51	463.51
Cambridge Tank	519.35	519.35	519.35	499.11	499.11	499.11
3.5 MG Tank	586.40	586.40	586.40	571.79	560.45	560.45
Blue Boy Standpipe	586.40	586.40	586.40	563.09	551.75	551.75
640 Tank	579.00	620.60	620.60	564.39	601.54	601.54
Future West Hill Reservoir	---	571.23	571.23	---	528.23	528.23
Supply Facilities Status						
208th Street/ 212th Street Wellfield	OFF	OFF	OFF	OFF	OFF	OFF
Armstrong Springs Wells	ON	ON	ON	ON	ON	ON
Clark Springs	ON	ON	ON	ON	ON	ON
East Hill Well	ON	ON	ON	ON	ON	ON
Garrison Creek Well	ON	ON	ON	ON	ON	ON
Kent Springs	ON	ON	ON	ON	ON	ON
O'Brien Well	OFF	OFF	OFF	OFF	OFF	OFF
Seven Oaks Well	ON	ON	ON	ON	ON	ON
RWSS POD #3	ON	ON	ON	ON	ON	ON
BPS Facilities Status						
Pump Station #3	ON	ON	ON	ON	ON	ON
Pump Station #4	ON	ON	ON	ON	ON	ON
Pump Station #5	ON	ON	ON	ON	ON	ON
Pump Station #6	ON	ON	ON	ON	ON	ON
Pump Station #7	ON	ON	ON	ON	ON	ON
Pump Station #8	ON	ON	ON	ON	ON	ON
Future West Hill BPS	---	ON	ON	---	ON	ON
Future 640 Zone BPS (Blue Boy)	---	ON	ON	---	ON	ON
Future 640 Zone BPS (POD #3)	---	---	ON	---	---	ON

Separate fire flow analyses were performed on the system to size distribution system improvements and calculate fire flow availability. The hydraulic model for the fire flow analyses contained settings that correspond to MDD events. All sources of supply that currently are available to the system during a peak period were operating at their normal pumping rates, and reservoir levels were modeled to reflect full utilization of operational, equalizing, and fire flow storage based on the maximum planning-level fire flow requirement. **Table 7-23** summarizes the operational conditions for the fire flow analyses for the existing and future planning periods.

Calibration

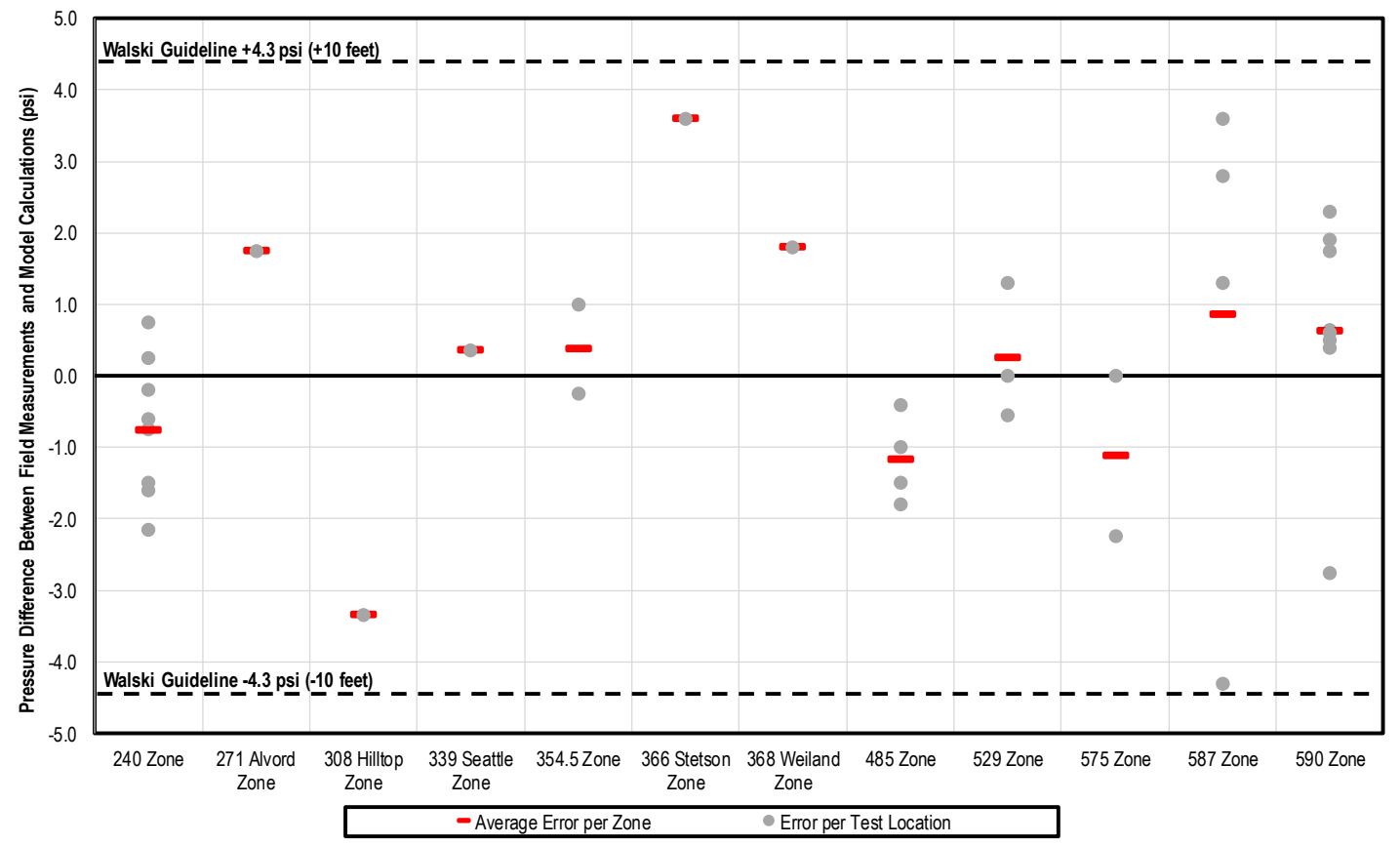
Hydraulic model calibration was completed during the preparation of this Water System Plan (WSP). Hydraulic model calibration is achieved by adjusting the roughness coefficients of the water mains in the model so the resulting pressures and flows closely match the pressures and flows from actual field tests under similar demand and operating conditions. Initial Darcy-Weisbach roughness coefficients were entered in the model based on computed estimates of the coefficients from available pipe age and material data. For example, older water mains were assigned higher roughness coefficients than newer water mains; thereby assuming that the internal surface of water pipe becomes rougher as it gets older. Additional calibration of the model was achieved using field flow and pressure data that were collected throughout the system during hydrant testing for this purpose.

Hydrant flow tests were performed at 51 locations in late 2017, with hydrant flows, static pressures, and residual pressures measured during each test for use in calibrating the hydraulic model. Telemetry data for each of the City's water system facilities were provided in 30-second intervals during the tests and used to initialize the settings of the facilities in the hydraulic model. Pressure transducers recording at 2-second intervals were installed throughout each pressure zone during the flow tests to verify the static and residual pressures at intermediate points in the system (between the water system facilities and the hydrant flow test locations). Hydraulic model calibration of the 51 locations was achieved by adjusting the roughness coefficients and connectivity of the water mains, adding check valves at appropriate locations, adding the "small" PRV within each PRV station in the hydraulic model, and updating BPS initial settings and controls. The identification of these differences was generally the result of sensitivity analyses, which consist of iterative model adjustments to assist in troubleshooting the cause of a discrepancy between field measurements and model calculations. Examples of sensitivity analyses performed for the City's hydraulic model include temporarily opening or closing a PRV to identify if the PRV opened in the field but not in the model (or vice versa); temporarily adjusting the pressure setpoints of pumps or valves to determine the impact on system pressures; or temporarily closing pipes or adding check valves to pipes to confirm the presence of a zone valve or check valve at pressure zone boundaries.

The hydraulic model's calculated head loss during the flow tests was within plus or minus 4.3 psi (10 feet) of the field-measured head loss at all 51 hydrants that were flow tested, and within 2.2 psi (5 feet) at 41 of the 51 hydrants. The accuracy of the calibrated hydraulic model is consistent with the guidelines published by Walski et al. (Walski) in the 2003 *Advanced Water Distribution Modeling and Management* book, which suggests that the hydraulic model is able to

predict the hydraulic grade line (HGL) to within 5 to 10 feet at model calibration points during peak demands. A summary of the difference between the hydraulic model's calculated head loss during the flow tests and the field-measured head loss at each flow test location is shown in **Chart 7-2**.

Chart 7-2
Hydraulic Model Calibration Results Summary



HYDRAULIC ANALYSIS RESULTS

Several hydraulic analyses were performed to determine the capability of the system to meet the pressure and flow requirements identified in **Chapter 5** and contained in WAC 246-290-230. The first analysis was performed to determine the pressures throughout the system under base year (i.e., 2016) PHD conditions. Subsequent analyses were performed to determine the pressures throughout the system under future 10- and 20-year PHD conditions. The results of the analyses were used to identify locations of low and high pressures. To satisfy the minimum pressure requirements, the pressure at all water service locations must be at least 30 psi during PHD conditions. In addition, the system should not have widespread areas with high pressures, generally considered to be more than 100 psi.

The City provides at least 30 psi to all existing service connections during PHD conditions, although there are multiple areas receiving less than 40 psi during PHD conditions, as shown in **Table 7-24**. Pressure zone improvements identified in **Chapter 9** increase the pressure above 40 psi at more than half of the low-pressure locations shown in **Table 7-24** within the 20-year planning period.

All water mains with pressures greater than 100 psi, as identified from the analyses, are generally located along pressure zone boundaries. Water services in these areas, as with any future services, are required to be equipped with individual PRVs to limit the maximum pressure to 80 psi. **Figure 7-1** presents a summary of the pressures provided throughout the water system during base year (i.e., 2016) PHD conditions.

Table 7-24
Pressure Analysis Summary

Land Use	Approximate Location	Existing Pressure Zone	Junction No.	Pressure (psi) 2016	+10 years w/ Proposed Improvements[1]	+20 years w/ Proposed Improvements[2]	+20 years w/ All Improvements[3]
Low Pressure Areas							
Single Family 6 Units/Acre	Neighborhood in cul-de-sac of Carter Pl, east of Van De Vanter Ave	339 Seattle Zone	J-2105	30	34	34	34
Single Family 6 Units/Acre	Near intersection of Reith Rd and S 253rd St	354.5 Zone	J-1674	32	32	32	32
Single Family 6 Units/Acre	Near intersection of SE 248th St and 120th Ave SE	590 Zone	J-26570	32	55	55	55
Parks and Open Space	Neighborhood just west of 124th Ave SE at SE 248th St	590 Zone	J-26236	33	55	55	55
Single Family 6 Units/Acre	Near intersection of SE 240th St and 116th Ave SE (First Christian Church)	590 Zone	J-2547	34	65	64	64
Single Family 6 Units/Acre	Neighborhood near SE 244th St and 119th Ave SE	590 Zone	J-2483	34	62	62	62
Single Family 6 Units/Acre	Neighborhood adjacent to and north of S 254th St and 45th Ave S	354.5 Zone	J-533	35	35	35	35
Single Family 6 Units/Acre	Neighborhood in cul-de-sac of SE 237th Pl, east of 112th Ave SE	590 Zone	J-2403	36	74	73	72
Single Family 6 Units/Acre	Near intersection of S 264th St and 34th Ave S	529 Zone	J-1732	36	36	36	36
Single Family 6 Units/Acre	Near intersection of E James St and N Lenora Ave	240 Zone	J-131	38	39	39	40
Medium Density Multifamily	Near intersection of S 248th St and 98th Ave S	485 Zone	J-1601	39	39	39	40
Single Family 4.5 Units/Acre	Neighborhood near 94th Pl S and S 216th Pl	240 Zone	J-25901	39	40	40	40
Single Family 8 Units/Acre	Adjacent to 98th Ave S, between S 248th St and S 243rd St	485 Zone	J-2091	40	40	40	42
Single Family 6 Units/Acre	Approximately the 9700 block between S 239th Pl and S 243rd St	485 Zone	J-26787	41	41	41	43
Single Family 6 Units/Acre	Near intersection of 94th Ave S (Hamilton Rd) and S 233rd Pl	485 Zone	J-2036	42	42	42	45
High Pressure Areas							
Single Family 6 Units/Acre	Neighborhood along 92nd Ave S, north of S 222nd St	485 Zone	J-25910	144	143	143	147
Medium Density Multifamily	Near intersection of Summit Ave N and E Smith St	485 Zone	J-472	129	129	128	131
Single Family 6 Units/Acre	Near intersection of Alexander Ave and E Cherry Hill St	485 Zone	J-1143	129	128	128	130
Single Family 6 Units/Acre	Neighborhoods along 100th Ave SE, north of S 228th Pl	590 Zone	J-26408	126	132	132	128
Single Family 6 Units/Acre	Near intersection of Reiten Rd and E Maclyn St	485 Zone	J-26929	124	124	124	125
Single Family 6 Units/Acre	Near intersection of Alvord Ave N and Spring Ave N	485 Zone	J-2367	120	120	120	123
Single Family 6 Units/Acre	Near intersecton of S 222nd St and 93rd Ave S	485 Zone	J-26933	120	120	120	123
Single Family 6 Units/Acre	Near intersection of E Cherry Hill St and Olympic Way	485 Zone	J-1589	120	120	119	121
Single Family 6 Units/Acre	NW side of Scenic Way neighborhood, near Central Ave S and E Titus St	339 Seattle Zone	J-750	114	118	118	118
Single Family 6 Units/Acre	Near intersection of 96th Pl S and 97th Ave S	485 Zone	J-2737	113	113	113	117
Single Family 6 Units/Acre	East side of S 243rd St neighborhood	587 Zone	J-263	110	105	106	106
Single Family 6 Units/Acre	Near intersection of SE 228th St and 101st Pl SE	590 Zone	J-1799	107	113	113	110
Parks and Open Space	Along Canyon Drive near Kent Meridian HS field	590 Zone	J-26746	105	112	112	105
Single Family 6 Units/Acre	Near intersection of 104th Ave SE and SE 267th St	590 Zone	J-648	105	114	114	107
Single Family 6 Units/Acre	Neighborhood near intersection of S 262nd St and 46th Ave S	529 Zone	J-1653	103	103	103	104
Parks and Open Space	Near intersection of S 252nd St and 97th Pl S	590 Zone	J-641	102	108	109	101
Medium Density Multifamily	Near intersection of Lake Fenwick Rd and 46th Ave S	354.5 Zone	J-993	101	101	101	101
Single Family 8 Units/Acre	Neighborhood along Kensington Ave S, south of Reiten Rd	339 Seattle Zone	J-1576	97	101	101	101

(1) Includes 10-year CIP projects presented in Chapter 9, and assumed high priority water main replacement improvements.
(2) Includes 20-year CIP projects presented in Chapter 9, and does not include medium or low priority water main replacement improvements.
(3) Includes 20-year CIP projects presented in Chapter 9, and all medium and low priority water main replacement projects.

The second set of analyses was performed to determine the capability of the water system to provide fire flow throughout the water system under base year MDD conditions. A separate fire flow analysis was performed for each node in the model to determine the available fire flow at a minimum residual pressure of 20 psi in the main adjacent to the hydrant and a maximum allowable water main velocity of 8 feet per second (fps). More than 3,600 fire flow analyses were performed to comprehensively evaluate the water system. For each node analyzed, the resulting fire flow was compared to its general planning-level fire flow requirement, which was assigned according to its land use classification. As is typical of most water systems, the City's distribution system was constructed to meet fire flow requirements that were in place at the time of construction. Land use classification changes and/or increases in fire flow requirements over time may create deficiencies. A summary of the results of the base year (2016) fire flow analyses is presented in **Figure 7-2**.

Table 4-11 in **Chapter 4** lists the general planning-level fire flow requirements for each land use classification. Since the fire flow requirement varies for buildings within each land use classification, the land use based fire flow requirements are only used as a general target for the primary purpose of the system-wide analyses that were performed for this WSP. Additional improvements may be needed in areas where actual fire flow requirements exceed the planning-level targets and shall be the responsibility of the developer. The results of the fire flow analyses were used to identify undersized water mains and proposed water main improvements based on the general planning-level fire flow requirements and current design criteria, which is not necessarily the same requirements and criteria that were in place when current developments and water main were constructed. The Puget Sound Regional Fire Authority provided the City the fire flow requirements for the largest structures in each pressure zone if the structures were to be new construction based on current regulations and guidelines. These fire flow requirements are shown in **Table 7-25**, along with the fire flow availability at these locations in the existing system, for future planning periods in the City's existing system, and for future planning periods with the improvements identified in **Chapter 9**.

Table 7-25
Large Structure Fire Flow Analysis Summary

Location Description	Address	Existing Pressure Zone	Junction No.	Available Fire Flow (gpm) 2016	+10 years w/ Proposed Improvements[1]	+20 years w/ Proposed Improvements[2]	+20 years w/ All Improvements[3]	Target Fire Flow (gpm)
Amazon Fulfillment Center	20403 68th Ave S	240 Zone	J-26014	4,666	3,749	4,647	6,000	4,600
Carpet Exchange	9021 S 180th St	240 Zone	J-26488	3,876	3,903	3,900	6,000	5,000
Farrington Court Retirement	516 Kenoshia Ave	240 Zone	J-27093	856	969	970	6,000	4,800
Kent North Corporate Park	7611 & 7691 S 180th St	240 Zone	J-27134	1,391	1,406	1,404	1,404	5,000
Regional Justice Center	401 4th Ave N	240 Zone	J-27091	1,910	1,878	2,801	6,000	5,000
Stafford Suites Retirement	112 Kennebeck Ave	240 Zone	J-779	740	900	1,248	4,684	3,450
Lake Fenwick Estate Apts.	24849 46th Ave S	354.5 Zone	J-27094	1,750	1,908	1,893	1,893	1,650
Kent Church of the Nazarene	930 E James St	485 Zone	J-2111	418	432	432	1,382	3,282
Fire Station 73	26512 Military Rd S	529 Zone	J-854	1,253	1,253	1,382	1,382	1,500
Star Lake Elementary[4]	4014 S 270th St	529 Zone	J-798	---	---	---	777	3,163
Trinity Reformed Church	3807 Reith Road	529 Zone	J-27096	1,416	5,649	5,927	6,000	2,013
Totem Middle School	26630 40th Ave S	575 Zone	J-27095	1,235	850	879	1,594	4,600
Cornerstone Baptist Church	25030 Military Rd	587 Zone	J-1749	1,414	2,581	2,522	2,217	1,725
Sunny Crest Elementary	24629 42nd Ave S	587 Zone	J-26671	1,198	1,199	1,207	5,039	3,594
West Hill Plaza	24700 36th Ave S	587 Zone	J-27092	(N/A)	2,376	1,763	6,000	2,200
Home Depot	26120 104th Ave SE	590 Zone	J-1100	5,010	3,457	3,338	6,000	4,600
Kent-Meridian High School	10020 SE 256th St	590 Zone	J-26269	4,046	4,035	4,012	6,000	4,600

(1) Includes 10-year CIP projects presented in Chapter 9, and assumed high priority water main replacement improvements.
(2) Includes 20-year CIP projects presented in Chapter 9, and does not include medium or low priority water main replacement improvements.
(3) Includes 20-year CIP projects presented in Chapter 9, and all medium and low priority water main replacement projects.
(4) Fire protection provided by Highline Water District.

Once all deficiencies were identified based on the general planning-level fire flow requirements, proposed water main improvements were included in the model, and pressure and fire flow analyses were performed throughout the system to demonstrate that the improvements will eliminate the deficiencies and meet the current flow and pressure requirements. These analyses were modeled under projected year 2028 and 2038 MDD conditions to ensure that the improvements are sized sufficiently to meet the future systems' needs. A description of these improvements and a figure showing their locations are presented in **Chapter 9**, and the results of the 20-year fire flow analyses is presented in **Figures 7-3** and **7-4**, based on the improvements scheduled to be completed within the 20-year planning period as identified in **Chapter 9** (and not including medium or low priority water main replacement projects). A summary of the fire flow deficiencies and limitations in the 2038 planning period with the proposed 20-year improvements is as follows.

- 240 Zone: No widespread limitation, fire flows largely localized issues with 6-inch or 8-inch main being located adjacent to land uses with fire flow requirements in excess of 3,000 gpm.

- 271 Alvord: Limited by 8-inch main downstream of PRV, which was installed in 2012. Fire flow in zone limited to approximately 1,300 gpm due to this piping.
- 339 Seattle: Limited by 6-inch main downstream of PRV, which was installed in 2006. Fire flow in zone limited to approximately 750 gpm due to this piping.
- 366 Stetson: Limited by 6-inch main downstream of PRV, which was installed in 2012. Fire flow in zone limited to approximately 750 gpm due to this piping.
- 368 Weiland: Limited by 6-inch main upstream and downstream of PRV, which was installed in 1993. Fire flow in zone limited to approximately 680 gpm due to this piping.
- 485 Zone:
    - South of SR 516: 6-inch main throughout neighborhood limiting fire flow to approximately 1,100 gpm.
    - North of 234th Street: limited by 8-inch main on either side of the 234th and 96th PRV. Fire flow in vicinity limited to 1,000 to 1,400 gpm.
- 590 and 640 Zones: Fire flow limitations largely localized issues at dead-ends, or as a result of 6-inch main within neighborhoods.
- West Hill Zones: Fire flow limitations largely localized issues at dead-ends, or as a result of 6-inch main within neighborhoods.

DEFICIENCIES

Several areas throughout the system have sufficient fire flow; however, high water velocities are experienced in the system because the water mains are undersized to carry the demands and fire flows at acceptable water velocities. Operating the system with high water velocities can potentially damage the system due to the high pressure surges that commonly occur with high water velocities.

Some areas of the system have water mains that are more than 50 years old, which is approaching or beyond the average life expectancy of water mains of this vintage. Approximately 23 percent of the City's water main is cast iron pipe. Most of the cast iron pipe is located in the older areas of the City. The City is planning to replace the aging water main in the future, as shown in the schedule of planned improvements in **Chapter 9**. All new water main installations are required to use ductile iron water main in accordance with the City's Water System Standards, a copy of which is included in **Appendix G**.

TELEMETRY AND SUPERVISORY CONTROL SYSTEM

This section evaluates the City's existing telemetry and supervisory control system to identify deficiencies related to its condition and current operational capability.

EVALUATION AND DEFICIENCIES

The water system has a Headquarters telemetry control panel at the Public Works Operations Building at 5821 South 240th Street. System facilities, including source, storage, and pumping, can be monitored with the telemetry system. The City performs regular calibration checks of the telemetry system components, including annual inspections of all telemetry recording instruments and mechanical flow meters. The City continually strives to improve the capabilities of the supervisory control and data acquisition (SCADA) system, and has plans to implement remote totalizer reading capabilities, which will allow for system-wide supply totals to be obtained instantaneously to allow for better recordkeeping of supply and consumption. There are no known deficiencies with the existing telemetry/SCADA system.

SYSTEM CAPACITY

This section evaluates the capacity of the City's existing water system components (e.g., supply, storage, and transmission) to determine the maximum number of ERUs it can serve. Once determined, system capacity becomes useful in calculating how much capacity is available in the water system to support new customers that apply for water service through the building permit process. The system capacity information, together with the projected growth of the system expressed in ERUs, as shown in **Chart 4-7** of **Chapter 4**, also provides the City with a schedule of when additional system capacity is needed.

ANALYSIS CRITERIA

The capacity of the City's system was determined from the limiting capacity of the water rights, source, transmission, and storage facilities. The supply capacity analysis was based on the limiting capacity of the supply facilities and the system's MDD per ERU.

The transmission capacity analysis was based on the total capacity of the transmission system with a maximum pipeline velocity of 5 fps for the PHD analysis and 8 fps for the MDD plus fire flow analysis. The transmission capacity analysis considered the limiting supply requirement between the system's PHD and the MDD plus the maximum fire flow requirement for the system. The transmission system includes the following components.

- 31-inch-diameter Kent Springs Transmission Main (240 Zone).
- 12-inch-diameter Kent Springs Transmission Main (590 Zone).
- 21-inch-diameter Clark Springs Transmission Main.
- 16-inch-diameter transmission main downstream of the Garrison Creek Well and Reservoir site.
- 16-inch-diameter transmission main downstream of the 208th/212th Wellfield site.
- 12-inch-diameter transmission main downstream of the East Hill Well site.
- Two 16-inch-diameter transmission mains downstream of the Guiberson Reservoir site.

The storage capacity analysis was based on the storage capacity for equalizing and standby storage and the computed storage requirement per ERU. Operational and fire flow storage capacity were excluded from the storage analysis because these components are not directly determined by water demand or ERUs. For the analyses, a reserve amount equivalent to the existing operational and fire flow storage requirements were deducted from the total available storage capacity to determine the storage capacity available for equalizing and standby storage. This storage capacity available for equalizing and standby storage was divided by the existing number of ERUs presented in **Chapter 4** to determine the storage requirement per ERU.

The annual water rights capacity evaluation was based on the existing annual water rights, as summarized in **Chapter 6**, and the system's average day demand per ERU. The instantaneous water rights capacity evaluation was based on the existing instantaneous water rights, as summarized in **Chapter 6**, and the system's MDD per ERU.

The ERU-based demand data was derived from the average day demand of the system and demand peaking factors from **Chapter 4**.

CAPACITY ANALYSIS RESULTS

A summary of the results of the existing system capacity analysis is shown in **Table 7-26**. The results of the existing (2018) system capacity analysis indicate that the limiting capacity of the system is storage, which can support up to a maximum of approximately 73,972 ERUs. The existing water system has a surplus of approximately 27,893 ERUs based on this limiting component.

Table 7-26
System Capacity Analysis

Description	Base Year 2016	Existing 2018	Projected 2028 (+10 years)	Projected 2038 (+20 years)
Demands Per ERU Basis				
Average Day Demand per ERU (gal/day)[1]	172	171	171	171
Maximum Day Demand per ERU (gal/day)[1]	373	371	371	371
Peak Hour Demand per ERU (gal/day)[1]	546	542	542	542
Water Rights Capacity: Annual Average Based				
Water Rights Capacity - Annual Average Based (gal/day)	30,134,126	30,134,126	30,134,126	30,134,126
Average Day Demand per ERU (gal/day)	172	171	171	171
Water Rights Annual Average Based Source Capacity (ERUs)	**175,500**	**176,674**	**176,674**	**176,674**
Water Rights Capacity: Instantaneous Based				
Water Rights Capacity - Instantaneous Based (gal/day)	46,002,240	46,002,240	46,002,240	46,002,240
Maximum Day Demand per ERU (gal/day)	373	371	371	371
Maximum Day Based Source Capacity (ERUs)	**123,216**	**124,040**	**124,040**	**124,040**
Source Capacity: Maximum Day Based				
Source Treatment Capacity - Maximum Day Based (gal/day)	36,227,520	36,227,520	36,227,520	36,227,520
Maximum Day Demand per ERU (gal/day)	373	371	371	371
Maximum Day Based Source Treatment Capacity (ERUs)	**97,035**	**97,684**	**97,684**	**97,684**
Storage Capacity				
Maximum Equalizing & Standby Storage Capacity (gal)	14,794,367	14,794,367	18,898,504	18,898,504
Equalizing & Standby Storage Requirement per ERU (gal)	200	200	200	200
Maximum Storage Capacity (ERUs)	**73,972**	**73,972**	**94,493**	**94,493**
Transmission Capacity: PHD Based (5 fps)				
Transmission Capacity (gal/day)	36,273,200	36,273,200	36,273,200	36,273,200
Peak Hour Demand per ERU (gal/day)	546	542	542	542
Maximum Transmission Capacity (ERUs)	**238,794**	**240,391**	**240,391**	**240,391**
Transmission Capacity: MDD + Fire Flow Based (8 fps)				
Transmission Capacity (gal/day)	35,222,880	35,222,880	35,222,880	35,222,880
MDD + Maximum Fire Flow Requirement (gpm)	16,629	16,867	17,375	18,208
Maximum Day Demand per ERU (gal/day)	373	371	371	371
Maximum Transmission Capacity (ERUs)	**151,741**	**151,831**	**149,860**	**146,627**
Maximum System Capacity				
Maximum System Capacity (ERUs)	**73,972**	**73,972**	**94,493**	**94,493**
Limiting Facility	**Storage**	**Storage**	**Storage**	**Storage**
Unused Available System Capacity				
Maximum System Capacity (ERUs)	73,972	73,972	94,493	94,493
Projected ERUs	44,854	46,079	48,049	51,283
Unused Available System Capacity (ERUs)	**29,118**	**27,893**	**46,443**	**43,210**

(1) Includes distribution system leakage.

A summary of the results of the 10-year projected system capacity analysis also is shown in **Table 7-26**. The 10-year projected system capacity analysis includes improvements that are planned to be completed within the 10-year planning period, as described in **Chapter 9**. The primary improvements that impact the system capacity analysis are the proposed construction of a West Hill Reservoir and the 640 Zone conversion, which increases the available storage volume in the existing 640 Tank. The results of the 10-year projected system capacity analysis indicate that the storage capacity increases to 94,493 ERUs, and the limiting component remains storage. The system is projected to have a surplus of approximately 46,443 ERUs in 2028 if the improvements are completed as planned.

The water system's projected 2038 capacity is 94,493 ERUs, based on the same storage limitations as projected in 2028. In 2038, the system is projected to have a surplus of approximately 43,210 ERUs if the improvements are completed as planned.

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